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Improving the energy efficiency of the New Zealand economy: A policy comparison with other renewable-rich countries

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ABSTRACT

The relevance of energy efficiency policy measures for renewable-rich countries could be different from those countries that have a limited share of renewables in their electricity generation mix, and are therefore likely to focus on low-carbon energy generation policies. This paper presents a comparative analysis of the energy efficiency initiatives of the three highest renewable-rich OECD countries, namely: Iceland, Norway and New Zealand. The paper then focuses on a comprehensive review of New Zealand's energy efficiency policies since a formal "Energy Efficiency and Conservation Act" came into force. This paper then highlights the future challenges for New Zealand and offers some policy recommendations, which may also be applicable for other renewable-rich countries.

1. Introduction

The energy sector is currently experiencing a multifaceted challenge, whereby energy decision-makers are dealing with energy access, energy security, and environmental concerns altogether (Omer, 2009; Van den Bergh, 2011). Energy specialists have identified energy efficiency as a multipronged approach to address these concerns (Tanaka, 2008). The significance of energy efficiency towards achieving increasing self-sufficiency and energy security is ever increasing, and promoting both energy efficiency and energy conservation amongst different sectors are impactful instruments to extract additional benefits beyond energy cost savings (Dixon et al., 2010; Zhou et al., 2010). The importance of energy efficiency is thus being recognized globally (Omer, 2009; Tanaka, 2008; Dixon et al., 2010; Zhou et al., 2010) with energy agencies of different countries working actively to introduce and implement a variety of energy efficiency policies to promote and address the issues towards establishing a sustainable energy mix.

On the other hand, the level of interest and importance of the energy efficiency varies greatly with the countries' existing electricity generation mix. When countries have abundant renewable energy sources, their approach to energy is distinctly different from the countries that have a lack of such resources, or are still struggling with the integration of renewable sources into their electric grid. For example, countries like New Zealand differ in many ways from other countries, and one of the important distinctions is a high renewable generation portfolio. New Zealand is the country that has the third highest share of renewable energy in the total primary energy supply in OECD countries, and currently it is generating around 81% of its electricity from renewable sources (Ministry of Business, Innovation & Employment, 2016). Moreover, New Zealand retains the ambition of achieving 90% renewable-based electricity generation by 2025 (Ministry of Economic Development, 2011) without any direct subsidy, such as a feed-in-tariff. Iceland and Norway are two countries in the OECD that are ahead of New Zealand in terms of the proportion of renewable energy in their total primary energy supply. Fig. 1 shows the map of these three countries, their land area, population, and the share of renewable energy in total primary energy supply. There is a common tendency towards increased extraction of renewable sources in these

Abbreviations: ACEEE, American Council for Energy Efficient Economy; BRANZ, Building Research Association of New Zealand; CO_2, Carbon-di-oxide; EECA, Energy Efficiency and Conservation Authority, New Zealand; GDP, Gross Domestic Product; GWH, Gigawatt hours; HSBC, Hong Kong and Shanghai Banking Corporation; IPCC, Intergovernmental Panel on Climate Change; IEA, International Energy Agency; Ktoe, Kiloton of oil equivalent; MBIE, Ministry of Business, Innovation and Employment, New Zealand; MEPS, Minimum Energy Performance Standard; M&V, Measurement & Verification; NZD, New Zealand Dollar; NZGBC, New Zealand Green Building Council; OECD, Organization for Economic Cooperation and Development; PJ, Petajoule; PPP, Purchasing Power Parity; TPES, Total Primary Energy Supply; TFC, Total Final Consumption; TWH, Terawatt hours; toe, ton of oil equivalent; USD, United States Dollar; WEC, World Energy Council; WRI, World Resources Institute

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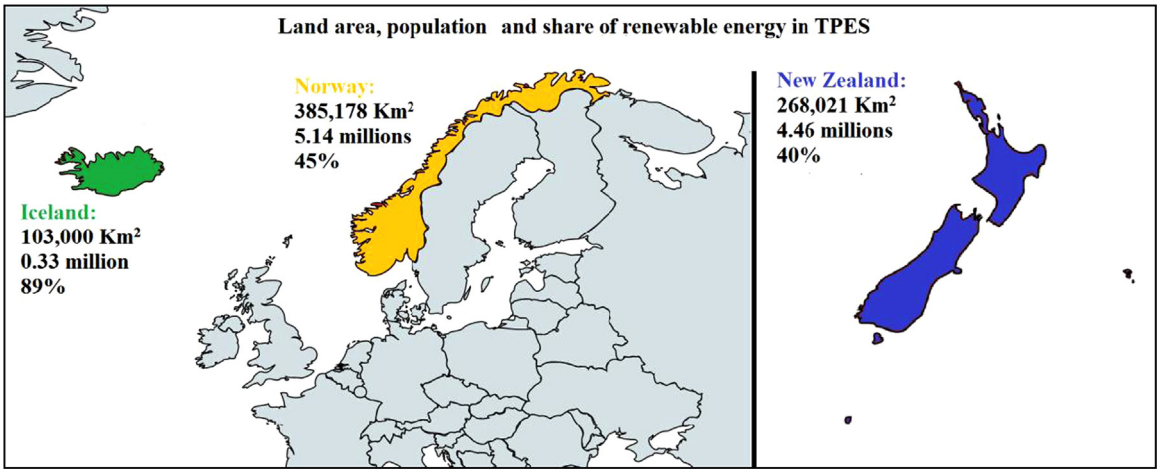

Fig. 1. OECD top three renewable-rich countries and share of renewable energy in TPES.

three countries. However, it is important to consider and understand their approach to energy efficiency at the same time.

The primary focus of this paper is thus to obtain an understanding of how these three countries (Iceland, Norway and New Zealand) are dealing with energy efficiency in their economies, given that they are also significantly rich in terms of renewable energy sources (for electricity generation). Furthermore, this article also presents a comprehensive analysis of New Zealand energy efficiency policies, and includes the challenges and concrete policy recommendations in implementing such energy efficiency policies. Notably, this paper helps energy efficiency researchers and policy-makers to understand the context of energy efficiency policies, and identify the future opportunities, specifically for countries that are progressing towards increased renewable generation in their electricity system.

2. New Zealand energy sector overview

In the last four decades, New Zealand's total primary energy supply[1] has increased from around 9000 ktoe (380 PJ) to 21,000 ktoe (903 PJ) and the energy mix has also changed significantly (Ministry of Business, Innovation & Employment, 2015). Currently, significant changes and challenges to the particular electricity sector are also being experienced (Nair and Zhang, 2009), in the context of ensuring security alongside highly distributed renewable generation.

Figs. 2 and 3 indicate the growth in total primary energy supply since 1974, and the mix of different energy sources in total primary energy supply in the year 2015 respectively. In the year 2015, the total primary energy supply was 906.87 PJ and oil accounted for around 32% the total primary energy supply. Oil continues to dominate New Zealand's overall energy mix (Ministry of Business, Innovation & Employment, 2016), and this makes the country's energy security situation vulnerable, in terms of supply disruptions and international price spikes, which can make the energy market unstable in a short-term as well as long-term. In the year 2015, 335.53 PJ of oil was imported, which is 25.44% higher than it was imported in 2000 (Energy Statistics, 2015).

With around 40% of the total primary energy supply from renewable resources, New Zealand is the third highest country in the OECD, shown in Table 1. There was a rapid increase of renewable energy in the energy mix of New Zealand in recent years, which is being driven mainly by increasing electricity generation from geothermal and wind sources. Currently, New Zealand has around 81% renewable-based electricity generation (Ministry of Business, Innovation & Employment, 2016), and the government has a plan to increase it up to 90% by 2025 (Ministry of Economic Development, 2011). New Zealand is continuing to increase its renewable electricity contribution, not only through large, utility-scale renewables, but also through small-scale implementations without any policies like feed-in-tariff or subsidy policies (Byrd et al., 2013). In recent years, this renewable progress is being continuously tracked on a quarterly basis (Energy Statistics, 2015), and the government is making all other efforts for the efficient extraction of these renewable energy sources.

In New Zealand, energy-related greenhouse gas emissions account for 43% of the total greenhouse gas emissions, and this is basically from the fossil fuel used in transport, manufacturing, construction and electricity generation (New Zealand Business Council for Sustainable Development, 2011). The total liquid fuel used is responsible for more than 57% of emissions, followed by 23% country's emissions from natural gas (see Fig. 4). Considering the energy consumption, import dependency and the GHG emission profile, the transport sector is considered as one of the priority sectors for New Zealand, and this provides a significant opportunity for reducing energy demand, as well as greenhouse gas emissions, in the near future (New Zealand Business Council for Sustainable Development, 2011; Bart van Campen and Kirkpatrick, 2007).

3. Methodology

This paper provides a comparative analysis of the national efforts on the energy efficiency of the three renewable-rich OECD countries i.e. Iceland, Norway and New Zealand. Amongst these, it was identified that New Zealand has taken significant national strategies and is currently implementing a variety of sector-specific energy efficiency policies as compared to the other two countries. Therefore, a detailed review of the aim, processes, and outcomes of energy efficiency policies of New Zealand has been presented in this paper. Based on this extensive review, and the study of the other cross-sectoral policies (which have the potential to alter the energy sector conditions), sector-wise current challenges and future opportunities for further energy efficiency improvement are also identified.

3.1. Data collection and comparative analysis of policy initiatives

All the data for the New Zealand's policy research is obtained from the International Energy Agency (IEA) statistics database, as well as the New Zealand's Ministry of Business, Innovation and Employment energy database. For the comparative analysis of the three countries

[1] Total primary energy supply (TPES) is the total energy supplied for usage in New Zealand. This is estimated as domestic production plus imports, and subtracting exports and energy used for international transport (Energy Statistics, 2015).

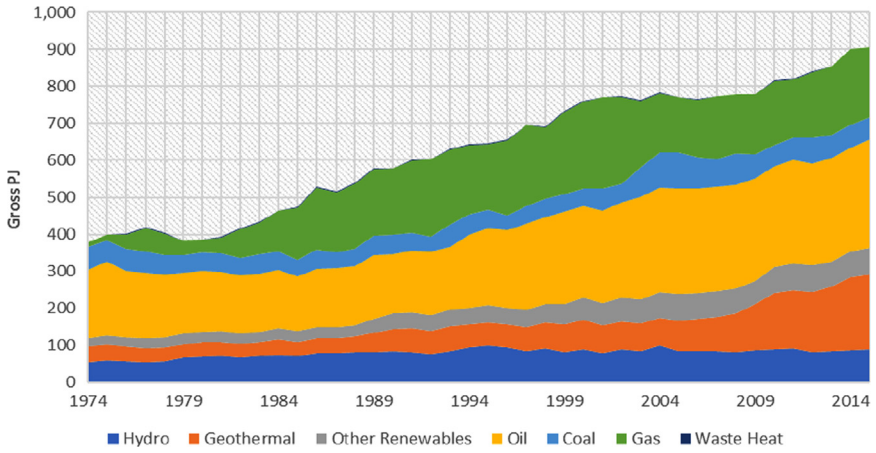

Fig. 2. Total primary energy supply by fuel (Source: Energy in New Zealand, MBIE, 2016).

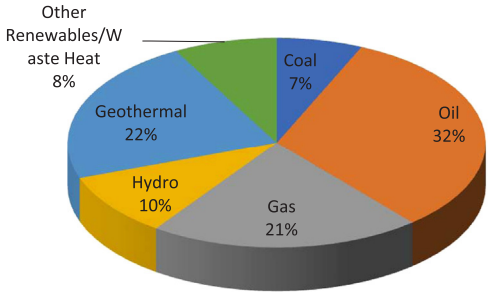

Fig. 3. Energy mix (Source: Energy in New Zealand, MBIE, 2016).

Table 1
Share of renewable energy in TPES in 2015.

Country	% of renewable energy in TPES	Renewable energy (PJ)
Iceland	88.3	206.4
Norway	46.13	572
New Zealand	40.7	351.8

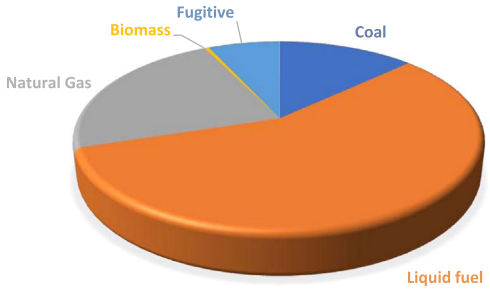

Fig. 4. Energy sector CO_{2eq}. emission (Source: Energy Greenhouse Gas Emissions, MBIE, 2016).

(Iceland, Norway and New Zealand), data was obtained from the statistics database of the IEA.

A comparative policy analysis method was utilized to understand the energy efficiency initiatives, and to obtain insight of how far the renewable-rich countries are in promoting the energy efficiency in their countries. This policy comparison will help policy-makers to understand how similar countries are performing on the same front. Sources utilized for this comparison are peer reviewed articles, IEA country-specific policy database, World Bank country specific reports and database, policy reports of the World Resources Institute (WRI) and World Energy Council (WEC), reports published by ACEEE, industrial reports and the energy database and published reports of the respective countries. A report on "International Energy Efficiency Scorecard 2016" for the top 23 energy-consuming countries, published by ACEEE (Kallakuri et al., 2016), was closely followed as the analytical framework for comparing the national efforts on the energy efficiency of these three renewable-rich OECD countries. ACEEE publishes biennial International Energy Efficiency Scorecard and it has been recognized worldwide for comparing energy efficiency performance of different countries, and opening the debate among different stakeholders to promote energy efficiency in their respective countries. This report has established standard policy and performance matrix for comparing energy efficiency performance and therefore, the same methodology has been adopted for comparing the energy efficiency performance of these three renewable rich OECD countries.

3.2. Data and analysis limitation

It is challenging to analyze all the indicators of energy efficiency, and therefore, in this case, only the energy intensity patterns (as discussed in Section 4.1), and some of the major national initiatives, were analyzed. Sectoral or sub-sectoral level policies for the other two countries, and how these policies are performing, were not investigated in detail. The other limitation is that micro-level initiatives of the national government were not captured due to a lack of data and relevant information available online. Climatic conditions also affect the energy consumption pattern of a country due to different heating, cooling, and transportation requirements. These parameters were not normalized in the comparative analysis.

4. Comparative analysis of the national efforts on the energy efficiency

Iceland, Norway, and New Zealand share a common vision of efficient extraction of renewable energy sources, and these are the top three OECD countries in terms of the proportion of renewable energy in their total primary energy supply. Before delving into an energy efficiency comparative analysis, a snapshot of some of the important statistics of these countries is presented in Table 2 to frame the narrative. This shows that Norway's population is only 0.68 million larger than the New Zealand's population, while the GDP of Norway is 2.83 times larger than New Zealand. In New Zealand, transport is the highest energy-consuming sector, whereas industry consumes more in Norway. Unlike Norway and New Zealand, Iceland is a much smaller country in terms of population, as well as GDP and, therefore, the total primary energy supply is much less than these two countries. Similar to Norway, Iceland's industry is the highest energy-consuming sector, and it consumes at least five times more than its transport sector.

A literature review shows a significant body of analysis of

Table 2
GDP and energy consumption in 2014 (Source: IEA).

Country	GDP (billion 2010 USD)	GDP PPP (billion 2010 USD)	Population (millions)	TPES (ktoe)	TFC (ktoe)	Transport (ktoe)	Industry (ktoe)
Iceland	14.45	13.41	0.33	5865	2738	280	1431
Norway	458.96	307.97	5.14	28,746	20,114	4823	5812
New Zealand	162.07	150.43	4.46	20,564	14,303	4699	4563

comparative energy efficiency assessment of developing countries, developed countries, and for the countries that are highly energy intensive (Kallakuri et al., 2016), but none of the studies have addressed the issue of energy efficiency of renewable-rich countries. On a country-by-country basis, this study assigns a numerical score for each particular governmental initiatives/effort to help rank their overall performance in terms of energy efficiency. Ten different and very important national efforts have been considered. These are important parameters for an effective energy efficiency policy, and have been selected after carrying out an extensive study of different policy reports of various countries.

4.1. Scoring criterion for national efforts on energy efficiency

The parameters and their scoring methods, based on the published ACEEE methodology (Kallakuri et al., 2016), are discussed in the following sections.

4.1.1. Energy efficiency/conservation act

Energy efficiency offers a multi-faceted potential to achieve current and future development goals. The existence of an energy efficiency/conservation act in the country unambiguously signals the need and the priority of energy efficiency in the country (International Energy Agency, 2011, 2010). It encourages individuals, but most importantly, it forces businesses to show greater responsibility towards managing the energy as well as the environment. Thus, if the country has a specific energy efficiency/conservation act, 1 point was allocated. It was noticed that only New Zealand has an “Energy Efficiency and Conservation Act” and therefore it has been assigned one point whereas, Iceland and Norway have been allocated 0 points.

4.1.2. Dedicated government institution on energy efficiency/conservation

A specific government institution also demonstrates the government priority for energy efficiency, and therefore, this parameter was assigned 1 point. Norway and New Zealand both have dedicated organizations to implement the energy efficiency programs, and therefore they both were assigned 1 point. In the case of New Zealand, it is the Energy Efficiency and Conservation Authority (EECA[2]).

4.1.3. International cooperation on energy efficiency

Different countries across the world have taken different policy initiatives on energy efficiency, and international cooperation is a great way of learning from the experiences of other countries (Kallakuri et al., 2016). Each of the countries were allocated 1 point as they are collaborating with other countries through different regional and international organizations/associations[3] on energy related research and development, which includes energy efficiency as well.

4.1.4. National energy efficiency database

Before implementing the available energy efficiency potential, it is also important for the countries to have a national database where all the energy related information should be easily available, and it should be updated at regular intervals. This database should include national, as well as the sector-specific energy-related data. If the data is easily available and accessible, 2 points were allocated. In the case of moderate level accessibility, 1 point was allocated, and zero points were given if the data is hard to find or if it is not available comprehensively on the government's website. In this way, New Zealand,[4] Norway, and Iceland have been allocated 2, 2 and 1 marks respectively.

4.1.5. Changes in energy intensity

For the better understanding of energy efficiency of the economy, an economic ratio is considered (Raza et al., 2015). This is specified by the ratio between total primary energy supply (measured in ton of oil equivalent) and the gross domestic product (GDP).[5] Hence, energy intensity can be stipulated as energy consumption per unit of GDP (Keong, 2005). It can also be normalized on a purchasing power parities (PPP) basis to make this more comparable with other currencies. In this case, the countries were ranked by comparing the improvement in energy intensity between 2000 and 2014. The total points allocated for this parameter was 2 points. Norway, which has performed best in terms of energy intensity (a decrease of 18.18%), was given 2 points followed by New Zealand (a decrease of 12.5%) which has been given 1 point. Iceland had an increase of 33.33%, and therefore, it has been given zero points.

4.1.6. Energy efficiency spending including R&D

This metric is based on the total investment in energy efficiency, which includes the research and development of the energy efficiency technologies and policies in the country. For comparing the countries in terms of investment, the total annual spending by the government was evaluated, as it can indicate the government's commitment to energy efficiency (Kallakuri et al., 2016; International Energy Agency, 2010). Finding the investment particularly for energy efficiency was the most challenging task as most of the investments were made in the name of sustainable development projects and not specifically in the name of energy efficiency, however, it includes the energy efficiency projects as well. Therefore, the total investments in sustainably related projects were considered for this comparison. After the study of several reports, it could be concluded that with around $4.3 billion New Zealand (Cabinet Policy Committee, Office of the Minister for the Environment, 2007) was the country with the highest investment. Norway and Iceland are investing around $1.7 billion (ABB, 2012) and $10.13 million (Clean Energy Research Programs in Iceland, 2016) annually on energy efficiency focused sustainability projects. In terms of share of total GDP; New Zealand, Norway and Iceland are spending around 2.65%, 0.37% and 0.07% on energy efficiency focused sustainability projects. This parameter was assigned 3 points if more than 2% of total GDP is invested, 2 points if between 1% and 2% is invested and 1 point if less than 1% is invested in energy efficiency focused sustainability projects. In this way, New Zealand, Norway, and Iceland were allocated 3, 1 and 1 point respectively.

4.1.7. Energy efficiency financing programs

This metric shows the government's initiative to encourage private investment in energy efficiency. The upfront cost and initial lack of

[2] www.eeca.govt.nz.

[3] http://www.mbie.govt.nz/info-services/sectors-industries/energy/international-relationships.

[4] http://www.mbie.govt.nz/info-services/sectors-industries/energy/energy-data-modelling/statistics.

[5] Total primary energy supply is sometimes also defined as total energy consumption.

faith are still the most common barriers to energy efficiency investment and government's support through loan programs, tax rebates, and other such mechanisms help to overcome such barriers, and push the market to move towards the energy efficient interventions (Kallakuri et al., 2016). It was found that all three countries have some kind of loan program and tax policies to promote energy efficiency and sustainable technologies and therefore, the maximum 3 points were allocated to each of these countries.

4.1.8. Availability of energy service companies

Energy Service Companies (ESCOs) are the businesses that basically promote, develop, manage and implement energy efficiency projects in the facilities (International Energy Agency, 2010). These agencies bridge the gap between the government and private industries by making use of their knowledge of technical and financial instruments to help businesses to improve their energy efficiency in a cost-effective manner. The presence of these companies in the country and the collaboration of government with these companies' shows the effort, which has been taken for the integration of energy efficiency in the country. This index was assigned 2 points and the highest point was given to New Zealand as the ESCOs information was very easily available on the EECA's website.[6] After an extensive review of the energy companies of Norway, it was found that there are companies that are providing such services, but no information was readily available on the government's website. It was also found that most of the ESCOs provide their services from outside Norway. Therefore, Norway was given only 1 point. Iceland was awarded zero points because of the absence of relevant data on the government's website, or in any of its governmental reports. The difficulty Icelandic companies' face in obtaining this information justifies this score.

4.1.9. Energy efficiency integration with other sectoral policies

National energy efficiency mission should also include the strategies that integrate the energy efficiency with at least the most energy consuming sectors of the country. This integration will ensure that the sectors are achieving the full potential of energy efficiency; thus contributing towards the national goals (International Energy Agency, 2011; Energy Charter, 2005). A maximum of 2 points were allocated for this parameter. If the country has at least one such mandatory policy, 2 points were allocated. In the case of only voluntary policy, 1 point was allocated, and if the country does not have any policy, or if the information is not available easily, zero points were allocated. New Zealand, Iceland, and Norway were allocated 2 points as they have some of the mandatory policies targeting electric appliances, buildings, and so forth.

4.1.10. National energy efficiency/conservation goals

A specific and quantified energy efficiency/conservation goal of the country shows the government's priorities on energy efficiency, and these goals can help measure the progress of an economy in terms of energy efficiency. A total of 3 points were allocated for this parameter. If the country has a quantitative goal of energy saving or reducing the energy intensity, 3 points were allocated, and if the country has defined the national target in terms of carbon emission and not in terms of energy saving or energy intensity then 2 points were allocated. If the country does not have any quantitative goal, but has a mission statement in their energy plan, then 1 point was allocated. In this way, New Zealand,[7] Iceland, and Norway were allocated 3, 2, and 1 point respectively.

4.1.11. Overall comparison

Table 3 presents the individual as well as the final score for all these three countries. It can be seen that New Zealand with 19 points scores the highest, followed by Norway, which has 15 points. Iceland lacks in terms of energy efficiency initiatives as compared to these two countries.

This comparison can help identify countries that are lacking in national efforts on energy efficiency. It is also important to note here that the total points do not show an exhaustive assessment of every aspects and initiative on energy efficiency. In fact, it is only based on certain national level initiatives, which are usually considered essential from the energy efficiency policy perspective, and therefore it should not be the only criterion for making the judgment on the energy efficiency initiatives of any country.

4.2. A brief report on Iceland, Norway and New Zealand energy indicators and policies

Iceland has plenty of natural resources, and it uses its resources to generate around 99.99% of its electricity generation. Unlike other countries, Iceland's primary focus is on the efficient extraction of these renewable sources rather than targeting policies for efficient utilization of fossil fuels or electricity. Fossil fuels are exclusively being used where the use of renewable sources is not technologically feasible (National Energy Authority Iceland, 2006). Energy consumption per capita of Iceland is also amongst the highest in the world,[8] mainly because of high energy consuming aluminium smelters operating in the country. The government's main focus is on expanding the network of renewable sources across the country and utilizing it at the maximum possible limit. Although energy efficiency is considered important, there are no specific targets, policies or acts to improve energy efficiency. Iceland uses almost four times extra energy per unit of GDP (on a PPP basis) than Norway, the country with the lowermost energy intensity among these three highly renewable-rich countries. For a reduction of CO_2 emission, the government has ratified the Kyoto Protocol and released a strategy in February 2007 for reducing greenhouse gas emissions by 50–75% of the 1990 baseline by the year 2050 (Energy Charter, 2005; IEA Policies and Measures Database – Iceland, 2016).

New Zealand and Iceland are dependent on around 22% and 14% energy imports respectively (International Energy Agency, 2017). Unlike Iceland and New Zealand, Norway is the third largest energy exporter in the world (Russia and Saudi Arabia are the first and second largest) (International Energy Agency, 2011). In 2014 Norway exported around 167 Mtoe (6992 PJ) (International Energy Agency, 2017). Furthermore, Norway has the second maximum share of renewable energy in the total primary energy supply of the OECD countries. In 2002, the Norwegian government established a dedicated agency "Enova SF" for elevating energy efficiency and renewable energy in the country. The Norwegian government has established a dedicated energy efficiency and conservation fund for undertaking several projects in different sectors of their economy (International Energy Agency, 2011). Energy intensity in Norway is close to the average of OECD countries. Its energy intensity has improved significantly (average annual decline of 1.4%) during the past years (International Energy Agency, 2011). Norway has a number of energy efficiency policies, and actions targeted the sectors where the greatest effect can be observed (Enova and Enova, 2014). The Norwegian government has not specified a national plan on energy efficiency, nor has identified any quantitative targets, but Enova has set the objective of delivering 40 TW h in energy efficiency, conservations and renewable energy by 2020. Norway retains the target to decrease the global greenhouse gas emissions by 30% of the Norwegian 1990 levels by 2020. Furthermore, Norway wants to be declared carbon

[6] https://www.eecabusiness.govt.nz/tools/programme-partner-directory/.

[7] https://www.eeca.govt.nz/assets/Resources-EECA/nz-energy-strategy-2011.pdf.

[8] Iceland's per capita energy consumption is 17.74 t of oil equivalent which is quite high as compared to Norway and New Zealand.

Table 3
Final scores of the countries.

Parameters (Total points allocated)	Iceland	Norway	New Zealand
Existence of energy efficiency/conservation law/act (1)	0	0	1
Government institution on energy efficiency/conservation (1)	0	1	1
International cooperation on energy efficiency (1)	1	1	1
National energy efficiency database (2)	1	2	2
Changes in energy intensity (2)	0	2	1
Energy efficiency spending including R&D in energy efficiency (3)	1	1	3
Energy efficiency financing programs (tax credits/loan program) (3)	3	3	3
Availability of energy service companies (2)	0	1	2
Energy efficiency integration with other sectoral policies (2)	2	2	2
National energy conservation/efficiency goals (3)	1	2	3
Total points (20)	**9**	**15**	**19**

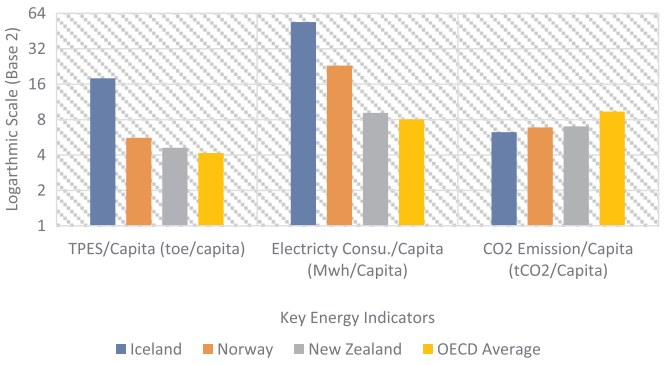

Fig. 5. Key energy indicators and comparison with OECD average (Source: IEA, 2016).

neutral by 2050.

Fig. 5 illustrates the key energy indicators for each of the countries and their comparison with the OECD in total. Wide variations in the key indicators provide a good understanding of the further opportunities for improvement.

The electricity efficiency work of the New Zealand government is funded through the "Electricity Levy[9]", a levy on all electricity users, which also funds the Electricity Authority (EA). EECA uses this levy to further increase the energy efficiency in residential, industrial and commercial sectors through the penetration of different energy efficient technologies. On the other hand, Iceland had introduced an energy tax, a levy on electricity and hot water, in 2010, but this was only temporary and expired at the end of 2012 (International Monetary Fund, 2011). While in Norway, the electricity levy is not mandated for all electricity users. Some of the facilities and households in Norway are exempt from the electricity levy (Espensen et al., 2014). In New Zealand, EECA has been structured as a national imperative and all taxpayers formally pay the electricity levy, which shows the significance of energy efficiency in New Zealand even though it is highly renewable. New Zealand's government is actively engaged in promoting energy efficiency through a variety of awareness program, funding, and technical support for project implementation (Ministry of Economic Development, 2011) and therefore, the country was chosen for a detailed review of the energy efficiency policies and exploration of future opportunities in the context of renewable-rich countries.

5. New Zealand energy efficiency strategies and regulatory initiatives

The energy efficiency strategy is one of the important initiatives of the New Zealand government for introducing sustainability, and to respond to climate change. The government believes that it will not only help in protecting the environment, it will also create new kinds of business opportunities to boost the economy (Ministry of Economic Development, 2007). The government is taking a multifaceted approach and trying to develop integrated policies for providing affordable, secure, and sustainable energy. The government has enacted the *Energy Efficiency and Conservation Act 2000*, which aims to promote energy efficiency and conservation, and renewable energy in the country, and covers different sectors, including: power generation, home, businesses, transportation, and so forth, to take sustainability to new levels. The government keeps the aspiration of 90% renewable-based electricity generation by 2025, provided the security of supply should not be affected (Ministry of Economic Development, 2011). Further, New Zealand is trying to maintain a rate of improvement in energy intensity by 1.3% per annum (average energy intensity improvement since 1990), while there is a 2% average increase in energy consumption every year (Energy Strategy and Policy, 2016), because of increasing populations and economic growth that lead to greater demand for energy services, such as: space heating, air-conditioning, lighting, cooking, transportation, industrial production, and office automation. Fig. 6 shows the total primary energy supply and the energy intensity pattern of the New Zealand economy on a PPP basis, since the time the energy efficiency act was enacted. A study conducted by the IEA shows that despite this unfailing improvement, the energy intensity of New Zealand in the year 2010 was bit higher as compared to the OECD average. It was mainly because of the higher share of energy-consuming sectors in its economy and there is much required in the future to adapt to a changing energy future (International Energy Agency, 2010). Fig. 7 shows the energy intensity comparison of New Zealand, other countries, and the OECD average. It can be seen that New Zealand's energy intensity is still lagging the OECD average, although an improvement in energy intensity performance, as compared to the year 2000, can be noticed.

After introducing the Energy Efficiency and Conservation Act, New Zealand framed the first Energy Efficiency and Conservation Strategy, which includes regulatory and non-regulatory measures, and is still in force. During 2003, the government framed the Sustainable Development Programme of Action (SDPoA) and it was the first sustainability approach, which was integrated to managing and governing mainly four areas: energy, water, cities, and child and youth development. In 2011, New Zealand released a ten-year strategy (New Zealand Energy Efficiency and Conservation Strategy 2011–2021) for improving the energy efficiency in different sectors. The primary objective for the energy sector was to ensure the delivery of energy facilities to all consumers in a most efficient and sustainable manner (Ministry of Economic Development, 2011). Maintaining a secure, sustainable and stable energy is critical for New Zealand's economic and social development and any kind of disruption in supply can have a huge impact on its economy (Ministry of Economic Development, 2009). New Zealand Government is taking a number of initiatives to produce and deliver different services in a more efficient way than it was being delivered. The policies and programs targeting different sectors and stakeholders are under implementation to make avail of the opportunities of emerging low carbon and no-carbon technologies (Ministry of Business, Innovation & Employment, 2015). The government is trying to provide better information about alternate energy choices and the most efficient means of delivering services with the current energy choices. The government is already engaged in implementing energy efficiency

[9] Levy rates are set based on the costs of Electricity Authority, the costs of the EECA electricity efficiency programs and the quantity of electricity generated, purchased and conveyed, plus the number of consumer connections (Levy Rates, 2015).

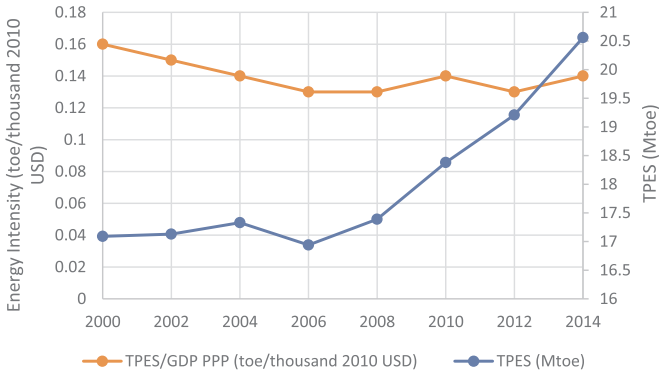

Fig. 6. Energy intensity and total primary energy supply in New Zealand (Source: IEA, 2016).

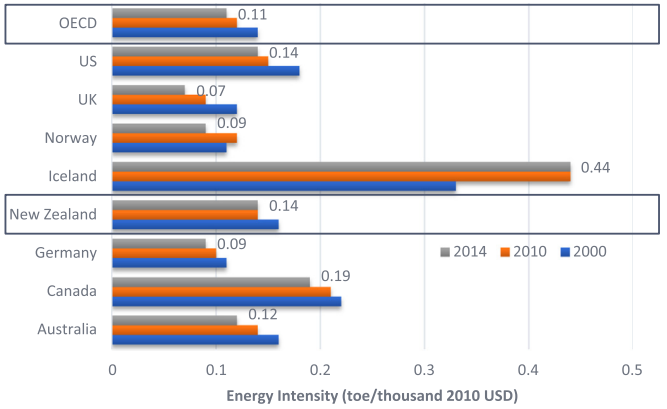

Fig. 7. Energy intensity comparison with different OECD countries (Source: IEA, 2016).

policies and taking actions to provide energy efficient and sustainable homes, transportation systems and augmenting the competitiveness in businesses through energy efficiency strategies along with providing enhanced and easy access information about alternatives and energy efficient options. New Zealand government has also endorsed the Kyoto Protocol, and derived a number of strategies and actions to reduce national greenhouse gas emissions, including an Emission Trading Scheme. During 2011, the government undertook to reduce carbon emissions by 50% from the 1990 baseline by 2050 (Ministry of Business, Innovation & Employment, 2015). New Zealand's energy policies are linked to most of the government policies, namely: economic development; climate change and sustainability; resource management; research and development, and other policies (Ministry of Economic Development, 2011).

5.1. New Zealand sector-specific policies

Policy measures are necessary to create a marketplace for efficient equipment, and also to motivate consumers towards long term cost effective energy efficient options. The main objective of any measure should be to accelerate the penetration of energy efficiency in various sectors of the economy (Eusterfeldhaus and Barton, 2011). In the New Zealand economy, the transport sector, with a 35.24% is the highest energy-consuming sector,[10] which is followed by the industrial sector with 30.96%. Other energy-intensive sectors include the residential, commercial and agriculture sectors, which in total consumes around 34% of total energy consumption of New Zealand. New Zealand is currently implementing many policies and targeting different sectors of the economy, which are described in the following subsections (Peng et al., 2015; Barton et al., 2013). A list of sector-specific policies of New Zealand has been consolidated in Table 4.

5.1.1. Residential energy efficiency strategies

Residential energy consumption in New Zealand accounted for 11.23% of the total energy consumption in 2015 (Energy Statistics, 2015). In 2015, with around 64.21 petajoules, the residential sector was the third highest energy consuming sector in the country. As per a study conducted by BRANZ,[11] the residential sector has a significant potential for energy efficiency improvement and reducing the related CO_2 emissions. It accounts for around 10% of CO_2 emissions, and it has been projected that each 1% improvement in the energy efficiency will result in 0.1% of CO_2 emission reduction at the national level (BRANZ, 2003). The sector has always been on the priority list of the New Zealand government as it is directly associated with health-related issues, because of the colder environment. The government has taken initiatives to provide efficient services, while maintaining comfort levels and a healthy temperature in the homes. In 2009, EECA introduced a program called *Warm Up New Zealand: Heat Smart Programme*. The objective of this program was to provide the necessary information on the home insulations and providing grants for different energy efficiency measures (such as home insulation, clean heating devices, etc.) in New Zealand homes. This program was basically a four-year program (2009–2013) and targeted essentially poor households who have a higher health risk. The target of this four-year program was to insulate 188,500 homes, which were overachieved by insulating 235,000 homes at the end of the program in September 2013 (Grimes et al., 2011). As a result of this program, there was an average 0.96% reduction in household electricity consumption and around 0.66% reduction in total metered energy used per annum (Evaluation of Warm Up New Zealand: Heat Smart, 2015). According to MOTU,[12] the net benefit was calculated worth around $1.3 billion over the expected lifetime of the initiatives delivered under the program which was one of the highest benefit program in the residential sector (Taylor Baines and Associates, 2006; Maidment et al., 2014).

After the success of this program, EECA has come out with a new program named *Warm-up New Zealand: Healthy Homes program*; a 3-year program and was initiated in 2013. This program was particularly for homes where children are living, and high health support is required. Again, similar to the previous program, the objective of this program was also to deliver a healthy and sustainable home to New Zealand communities. It basically provides free ceiling and underfloor insulation to low-income households to avoid the health risk caused by cold and serious disease. The program has several implementing partners to provide free insulation to households. The program provides 60% cost of the insulation, and the rest part is shared by the implementing partners. The government has budgeted $NZ50M for three years, and it is expected that the project partners support will exceed $NZ50M. The target of this program is to insulate around 46,000 additional homes over the three years' period. This program is currently active.

5.1.2. Commercial energy efficiency strategies

Commercial energy efficiency is a part of the "EECA Business Program". New Zealand businesses, which include industries and commercial establishments uses 50% of total energy consumption and accounts for more than 40% of New Zealand's energy-related carbon emissions (EECA Business Programs, 2017). New Zealand government developed a "Business Program" in 2009 to enhance the competition through energy efficiency and also to reduce the energy-related CO_2

[10] Transport sector energy efficiency policies have not been included for detailed review as another study particularly for transport sector is under way.

[11] www.branz.co.nz.

[12] MOTU is a research organization involved in economic and public policy researching work in New Zealand.

Table 4
Summary of sector-specific energy efficiency policies of New Zealand (EECA, 2017; IEA, 2017).

Target sectors for policies	Energy policies	Date effective/date ended	Return from the program
Development of strategic plan (Target: Multi-sectoral Policy)	Creation of Energy Efficiency and Conservation Authority	2000	
	Energy Efficiency and Conservation Act 2000	2000	
	New Zealand Energy Efficiency & Conservation Strategy	2001, 2011–21, 2011–2016, 2017–2022	
	Energy Domain plan	2006	
	Carbon Neutral Public Service	2007 (Ended in March 2009)	
	New Zealand Energy Strategy	2007	
	Low Carbon Energy Technology Fund	2008 (Ended in September 2011)	
Appliances	Minimum Energy Performance Standard	2002	Since the program began in 2002, it has given $560 M in savings to the country and reduction of carbon emissions equivalent to the amount produced by 300,000 cars in a year. Further, as of June 2016, 37% sales are the energy star qualified products.
	Energy Star	2005	
Building (Residential & Commercial)	Enhanced Provision under Building Code	2004	
	Energy-wise Home Package (This program superseded by Warm Up New Zealand: Heat Smart Programme)	2005 (Superseded)	
	Home Energy Ratings Scheme	2007 (Ended in 2008)	
	Warm-Up New Zealand: Heat Smart Programme (This program is superseded by warm-up New Zealand: Healthy Homes in September 2013)	2009 (Superseded)	Since it began in 2009, more than, 294,600 homes have been insulated and it has given the following benefits: – Reduced mortality rates – reduced annual household level hospitalization – Reduced pharmaceutical use cost – at least 2% reduction in metered energy cost
	Commercial Buildings Audit Programme (This program was superseded by NABERSNZ in May 2013)	2010 (Superseded)	
	NABERSNZ	2013	
Industry/Businesses	Efficiency Grants for Energy Intensive Businesses (This program is superseded by EECA Business Programme)	2005 (Superseded)	
	EECA Business Programme	2009	Since 2014, EECA has implemented several projects which are giving combined annual energy savings worth $36 M and 84,000 t of CO_2 emission reduction per annum.
	Compressed Air Scheme (This program was superseded by EECA Business Programme in 2012.	2011 (Superseded)	
Lighting	Electricity Levy to Support CFL Installation	2006 (Ended in 2007)	
	Establishment of Lighting Efficiency Stakeholder Group	2006 (Ended in 2008)	
	Efficient Lighting Strategy (This program was superseded by Right Light-consumer efficient lighting campaign in 2009)	2008 (Superseded)	
	Right Light: Consumer Efficient Lighting Campaign	2009	Sale of energy-efficient lamps increased from 12.8% in 2010 to 27.5% in 2015. 127 GWh savings worth $11.1 M saved in 2015–16.

emissions. This program was basically framed to penetrate energy efficiency by using optimal energy and embracing new sustainable energy technologies in the existing businesses. It covers three groups, namely: the top 200 energy users, large energy users (1000), and medium energy users (200,000+). EECA ensures to provide better consumer information, incentives, standards and best practices for energy efficiency improvements to these energy users.

New Zealand's commercial buildings consume around 20% of total electricity usage, and around 9% of total energy usage (EECA Business Programs, 2017). As per the World Energy Council's report on energy efficiency policies, published in 2013, this sector has the highest potential for energy efficiency improvements worldwide and therefore, most of the countries have set specific targets for energy savings in buildings. A major part of commercial buildings includes educational facilities, healthcare, offices, and other public housings. An estimation done by EECA informs that more than 50% energy saving is possible by improving energy efficiency in lighting, heating, cooling and ventilation systems. The New Zealand Green Building Council (NZGBC) is also actively working in a strong collaboration with EECA to accelerate and develop the adoption of green building practices and to deliver a sustainable built environment across New Zealand. In 2013, a program *NABERSNZ (National Australian Built Environment Rating system to New Zealand)* was launched by EECA and NZGBC to improve the energy efficiency of commercial buildings. This is a voluntary scheme for providing certified ratings of a building's energy consumption. EECA is giving different kinds of financial support (approximately 40% of the cost incurred) for improving the energy efficiency in all public buildings. Some of the important funding programs are for bringing expertise to the facilities for adopting energy saving practices, setting up of monitoring and targeting systems, and optimizing the heating, ventilation, and air conditioning based on continuous assessment of energy demand. EECA also funds for getting the expert advice during the building design, construction, or at refurbishment stage.

5.1.3. Industry energy efficiency strategies

In New Zealand the major energy intensive industries are manufacturing, food processing, and wood processing, which consume significant amounts of fossil fuels. As per the IEA, in 2012, the total

consumption of the industrial sector was around 4.56 Mtoe (191 PJ), which is the second highest energy-consuming sector after transport that consumed 4.69 Mtoe (196 PJ) in 2014 (International Energy Agency, 2017). The New Zealand government is providing different kinds of support, as well as funding, to invest in energy efficiency projects. *Group Wide Energy Management Support* and *Technology Demonstration Support* are the important initiatives to improve energy efficiency in a category of industrial facilities and to encourage collaboration among different enterprises to help them identify sustainable energy solutions. The *Group Wide Energy Management Support Program* basically focuses on those energy conservation projects by which actual and significant energy saving in a longer term can be achieved. The *Technology Support Grant* is designed to encourage the uptake of new technologies, which are not well proven, but has the potential to improve the industrial performance. The New Zealand businesses can collaborate with EECA registered technology suppliers to develop a demonstration project. At the same time EECA is also in the process of registering technology suppliers to take part in the program. The eligibility of the project gets evaluated on the basis of energy benefit, non-energy benefit, replicability, and its capability. The support is being given to mainly technologies for energy intensive sectors. The funding is available up to 40% of the project cost, and to a maximum of $100,000 (EECA Business Programs, 2017).

5.1.4. Agriculture energy efficiency strategies

The agriculture industry is commonly not considered as an energy intensive industry. Because of the energy security and climate change issues, the importance of sustainable agriculture is highlighted in literature recently. In New Zealand, the agriculture sector's consumption has increased significantly during last decade (from 27.95 PJ in 2001 to 35.33 PJ in 2014) (Energy Statistics, 2015), and therefore there is more interest in energy-efficient technologies resulting in a greater use of sustainable energy sources (Massey University, 2004). New Zealand's agricultural sector consumption is estimated to be around 5–6% of the total energy consumption, which is only a small fraction, but the New Zealand economy is heavily dependent on this sector. Agricultural products, with more than 70% of the total export earnings of the primary production industry, are the top commodity of New Zealand. Compared with other countries, New Zealand's agricultural industry has relatively low energy intensity due to the temperate climate. EECA is working towards improving farming energy efficiency by providing energy efficiency advice on variety of technologies that are relevant to this sector to make it more competitive while reducing their carbon footprints at the same time. EECA is also actively working with agricultural product manufacturers, particularly meat and dairy product producers, to identify energy efficiency opportunities in different technical processes (Wells, 2001).

5.1.5. Energy efficiency strategies for products and appliances

Because of the rapidly increasing penetration of appliances and other automatic equipment in the residential and commercial sectors, a dramatic increase has been seen in the electricity use during the last decade. It has also been seen that many of the common appliances consume more energy to perform the functions than they really need to. Like other countries, New Zealand has also felt a need to facilitate a rapid transformation of the market for equipment and appliances to highly efficient models. The *Standard and Labelling Program* has been recognized worldwide as the key strategy for energy efficiency improvements in household appliances (International Energy Agency, 2011). The primary objective of this labelling scheme is to offer the consumer a conversant choice about the energy savings and thereby the cost benefits through the particular product. This program intended to decrease the energy consumption of the appliances without degrading the quality of the services provided to end-users. According to EECA, the use of energy efficient appliances saved around 209 gigawatt-hours electricity worth $NZ50M in the financial year 2014–15. Since 2002, the *Standard and Labelling Program* has influenced the sale of 54 million products and appliances in New Zealand. The country currently has the following different programs to create a competitive market for energy efficient equipment and appliances:

5.1.5.1. Minimum Energy Performance Standards (MEPS). The *Minimum Energy Performance Standard* prescribes the maximum allowable energy consumption, or the minimum energy efficiency level, that the manufacturers have to achieve in their different products. In February 2002, the New Zealand government introduced the Standard to help improve the efficiency of the products commonly used in residential and commercial sector. The *Energy Efficiency (Energy Using Products) Regulations 2002* came into force on the 1st of April 2002 for the legal requirements that need to be fulfilled for all the affected products.[13] *MEPS* have been continuously updated over the years (2003, 2004, 2008, and 2011) in the last decade (van den Dungen, 2011) and the government is already on the way to strengthen and expand the program in a longer term.

5.1.5.2. Energy Rating Labels and Energy Star Programme. The *Energy Rating Labels* are a way to provide the information about the energy consumption performance of the product so that the consumer can make a decision about the energy and cost saving potential while purchasing appliances. *Star Rating* has been provided to show how much efficient the product is. Consumers can easily compare between the different models as well as different star rating products. *Energy Star Programme* is designed to meet a high standard of energy efficiency and the government awards the *Energy Star label* to the products which meets superior energy efficiency requirements set by the regulations. *Energy Star Programme* is one of the successful programs of EECA since 2005. This program is an integral part of the *Energywise Programme* which is to make people aware and encourage them towards energy efficiency products and practices. Currently, it is a voluntary program and doesn't cost manufacturers to take part in the programme. Manufacturers need to test their product for *Energy Star* qualifying criterion according a predefine test procedure by EECA and submit the detail for product registration under New Zealand *Energy Star Programme or Labelled Energy Star Programme.* EECA also has enforcement action for breaches of these regulations under the Energy Efficiency and Conservation Act 2000. Currently, a wide variety of businesses and brands of the products are taking advantage of being aligned with the *Energy Star Programme*.

5.1.6. Capacity building and awareness program

Energy Spot is an EECA awareness program using television commercials, since 2009, to help people to understand the importance of energy efficiency. As per the records of EECA it is one of the successful programs in terms of awareness as more than 2.4 million New Zealanders have viewed them. As per a survey conducted by EECA, this program reached 69% of New Zealanders and more than 39% New Zealanders have been motivated by this program to taken actions to reduce their energy consumption. Apart from this, EECA is also actively engaged through various social media platforms to communicate and interact with New Zealanders about the energy efficiency importance and initiatives. EECA is also managing a resource centre and publishes a variety of information that covers in-depth information, case studies, and technical guides on energy efficiency.

Right Light Program was also an important initiative by the New Zealand Electricity Commission, before it merges with EECA. This is a campaign to encourage New Zealanders about energy efficient lighting options for residential as well as businesses. The activities under this campaign have been funded through the electricity efficiency

[13] https://www.eeca.govt.nz/standards-ratings-and-labels/equipment-energy-efficiency-programme/products-under-the-e3-programme/.

component of electricity levy paid by the electricity consumers. EECA has a research centre/working group for consistent monitoring New Zealander's energy use patterns, developing and analysing energy efficiency options, and to take the best decisions for the low carbon economic growth of New Zealand (EECA Business Programs, 2017).

6. Challenges and future prospects

The driver for energy efficiency in New Zealand is a combination of strongly interlinked factors, including a reliance on income from dairy and tourism, with a foundation based on a clean and green image, adherence to rules and regulations, and a societal respect for the environment. The New Zealand economy is commonly seen to be successful as it is one of the least regulated economies in OECD (New Zealand Economic Overview, 2015). Recently, it has been ranked first in the world for social progression (which has been judged on the basis of basic necessities available, foundation of well-being and the level of opportunity to its citizens), and second in the world in terms of ease of doing business (Carey et al., 2015; 2015). Although New Zealand is providing quality services to the public, maintaining a stable economic environment, and supporting the business productivity growth, the crucial goal of the New Zealand government to speed up its economy with greater opportunity, security, and prosperity, is now more challenged with the need of tackling two major emerging energy challenges: energy security, and mitigating the impacts of climate change, which have strong linkages with the New Zealand economic responses (The Treasury, 2008). The largest challenge is not simply to improve the economic level of the country, but to transition towards a low carbon economy as well. Despite the enormous challenges, this also presents a significant opportunity for further improvement (Boshier, 1988). Reacting to these challenges is a foremost undertaking of the government with the introduction of the variety of energy efficiency policies, and regularly reviewing the energy efficiency and conservation strategies over the last ten years (Greenpeace Aotearoa/New Zealand, 2007). During these years, New Zealand has taken significant measures for improving the energy efficiency, but now continual investment is required even with the projects with low rates of return to get a long-term environmental benefit. Furthermore, despite the number of initiatives, the abundance of natural resources, and with this relatively small population of 4.5 million, New Zealand is still a net energy importer that indicates the existence of significant opportunities for greener resources, as well as energy efficiency opportunities that need to be explored.

6.1. Products and appliances' package policies

Equipment and appliances have been targeted by the most common measure of labelling and MEPS, which is one of the cost-effective ways to penetrate more and more energy efficient appliances in the market. Despite these efforts, there is still much potential in the existing building sector to make it more energy efficient with sustainable buildings. IPCC assessments suggest that, by 2022, carbon dioxide emissions can be reduced by 29% from using energy efficient products and appliances in buildings at no major cost (Levine et al., 2007). Now, the need of the New Zealand government is to focus on the package of policies, namely mandatory public procurement to improve the efficiency of this sector, which requires strong leadership and demonstration by the government (Kelly, 2012). Procurement policies could be used to create a demand for energy-efficient products, as well as the innovation in energy-efficient products. The mandatory procurement program needs to be aligned with the *MEPS* as well as *Star Rating Programs* to ensure the purchasing of efficient products in businesses and governments (OECD, 2008). All the public buildings should be mandated to use the highest energy star rated products. Suppliers, local and central government, and other stakeholders also need to be aligned to encourage efficient procurement in different sectors of the economy. New Zealand businesses and governments that have already introduced efficient procurement, reported between 8% and 30% improvements from the baseline, and now this needs to be replicated (Kelly, 2012; OECD, 2008; Jaffe and Stavins, 1994; Rosenberg and Winkler, 2011).

6.2. Improving the energy efficiency of New Zealand homes

Significant externalities like the financial crisis, immigration, and economic challenges, impact the energy usage, especially for island economies like New Zealand. The New Zealand's economy is also rapidly increasing (according to HSBC, the increases are 3.20% in 2014, 3% in 2013, 2.7% in 2012, and 1.4% in 2011), and as a result housing prices are rising radically, which will make this sector unstable. New Zealand does not have capital gain for property, and this potentially leads to owners buying and selling property in a shorter annual cycle, and therefore energy efficiency in such cases needs stronger drivers. Further, it is also important to highlight here that the energy intensity of New Zealand homes is slightly larger as compared to Iceland and Norway due to the traditional construction, which is for very temperate climates and hence not thermally efficient. Thus, thermal leakage is a major issue in New Zealand houses that needs to be managed in a much better way. Thermal time-constant efficiency can be improved alongside other benefits like load shifting, which also decreases the peak load losses, and will be helpful in improving the efficiency of New Zealand homes (Qureshi et al., 2011). State housing[14] stocks[15] are also not well maintained, and hence some requirements of energy efficiency should be introduced into any maintenance contracts. In a recent 2013 census by Statistics New Zealand, it was reported that the percentage of houses who retained their home (excluding those whose home was in a family trust), decreased from 54.5% in 2006 to 49.9% in 2013. It was also reported that 453,135 households rented their home in 2013 as compared to 388,275 in 2006, which is a significant increase for such a small country. Rapidly increasing housing prices are expected to further magnify the number of rented properties (Renting Households: National Trend, 2015; 2013 Census Quickstats About Housing, 2013) and energy efficiency in such a scenario will be really difficult to implement. Therefore, there is an urgent need to work on alternative policies that can be the most practical options to improve energy efficiency at realistic levels in such a scenario (Uitdenbogerd et al., 2007; Berry et al., 2008; Barton, 2012). New Zealand can follow some policies of rentals like in Germany (Germans prefer to rent a house and the home ownership in Germany was only 43% in the year 2013), where, for example, tenants have to pay higher price for heating charges based on consumption, and, at the same time, higher incentives are provided for energy saving to tenants, and for home-owners to adopt energy saving measures (Power Zulauf, 2011).

6.3. Immediate transition from CFL to LED lighting

New Zealand's lighting market is still very much 'inefficient'. In the residential sector, more than 80% of the light sources are incandescent bulbs. The industrial and commercial sectors are also dominated by inefficient lamps. New Zealand has approximately 370,000 road lighting luminaires, which are consuming approximately 116 GWh of energy per annum and there is a huge potential of savings by replacing it to LED lightings that can offer a great benefit at local, as well as national level (Verma et al., 2016; Verma et al., 2016). On such projects, the government should encourage the energy performance contracts as it motivates private funders to sustenance energy efficiency investments with minimum intervention of the government. Energy

[14] State houses are owned by New Zealand government for efficient and effective management.

[15] There is a new initiative by the new government to involve private partnership in state house ownership.

efficiency obligations for financing part of energy efficiency projects by traditional energy companies can also be one of the effective tools for promoting public projects (Davis, 2012; Cheng and Cheng, 2006).

6.4. Increasing the awareness about the energy efficiency programs and behavioural change opportunities

EECA is already working towards educating people and making them aware about energy efficiency, but more simplification and unification of information channels are required. For the consumers, local awareness centres or dedicated area managers need to be appointed to facilitate them understand of the energy efficiency indicators and build their capacity to monitor and control their electricity usage. In addition to the technologies and technological understanding of consumers, the behavioural aspects of consumers also need to be changed via a variety of approaches of ICT (Information, Communication and Technology). There is a strong linkage between individuals' emotions and visual images and therefore, a strong energy visualisation program to change the user's behaviours needs to be rolled out so that users can continuously monitor their energy consumption, including aggregated and disaggregated energy, and accordingly can take appropriate actions.

6.5. Developing a robust measurement and verification (M&V) system

As of now there is no robust M&V system to check the performance guarantees of energy efficient technologies and their useful life. Manufacturers, installers, as well as owners are only responsible to follow standards and best practices to achieve a maximum level of energy efficiency. M&V is really necessary for determining the impact of these kinds of energy efficiency policies, and whether the policy is able to achieve the goals that have been envisaged. This is the only tool, which has the potential in developing, strengthening and determining future policy goals. How the M&V can help to utilize the product to their full efficiency during their life cycle, and how it can be integrated with different policies, needs to be explored. Adopting an energy efficiency policy framework, which incorporates life cycle assessments of energy efficient technologies can help to achieve the policy goals more effectively (Quirk, 2009).

7. Conclusion and policy implications

This paper presents a comparison of energy efficiency initiatives of the top three renewable-rich OECD countries, and a detailed review of energy efficiency policies of New Zealand, along with some opportunities for further strengthening of its policies. It is well recognized that Iceland, Norway, and New Zealand are abundant in natural resources, but there is a strong motivation to exploit the opportunities of energy efficiency at the same time, while integrating the renewable energy in future strategies. Energy efficiency in several cases has been recognized as a no cost solution towards sustainability, which should be considered by targeting quantitative and qualitative long-term, as well as, short-term policies and strategies. Any country in the world that has ample natural resources, and is making exhaustive use of these sources, also needs to regularly assess the opportunities for energy efficiency improvements and prioritize the sectors with time-bound energy efficiency policies.

New Zealand is quite different as compared to Iceland and Norway with respect to the opportunities and drivers for energy efficiency. For Iceland and Norway, primarily transportation and industrial emissions need to be addressed, whereas, for New Zealand, agricultural emissions is an additional issue, as this sector has a large contribution to the economy. In contrast to Iceland and Norway, an electricity levy is also paid by all New Zealanders and hence, emphasizing the importance of energy efficiency. Unlike Iceland and Norway, energy sector reforms in New Zealand have been recognized at different governmental levels, and the impact of these reforms has been felt throughout the economy. Some of the most successful programs are the residential insulation programs, product standard and labelling program, and providing grants to businesses to implement energy efficiency measures, and these policies are still active. The New Zealand government, through its Energy Efficiency and Conservation Authority, is continuously updating regulations and the energy efficiency strategies to create a competitive market for energy efficiency, and to meet its obligations to carbon emissions. However, the need is to drive energy efficiency policies in synchronization with the technological advancements and international benchmarks in specific areas. New Zealand government is trying to widen its span on the enforcement of energy efficiency policies by covering more sectors of the economy. But, again it is not clear whether New Zealand will be able to maintain an energy intensity improvement of 1.3% in subsequent years (it is also important to highlight here that New Zealand is still slipping behind the energy intensity performance of the average of the OECD countries), and what will be the role of energy efficiency? The government has targeted a 90% share through renewable energy by 2025, but the penetration of energy efficiency measures is still uncertain. The long-term specific vision in terms of mandatory energy efficiency regulations is also needed for energy intensity reductions, as well as reducing energy usage in the major energy consuming sectors. Consumer awareness, public procurement, developing a strong measurement and verification system, revisiting the housing energy efficiency strategies, and promoting the energy efficiency research and product development, are the key opportunities for the further strengthening of the energy efficiency policies of New Zealand. In addition, the key enabling technologies such as distributed generation technologies, battery storage technologies, smart grids, and electric vehicles have already started paving the way for profound changes in New Zealand and, we need to make sure that these key technologies are not only reliable in the longer term but, also operating at the most efficient level to realize its maximum benefit. Software/Digital concepts such as blockchain, big data, robotics, Internet of Things are also bringing enormous potential to make the energy sector more efficient than ever before and it is ready to shape not only energy consumers' habits but also those of energy suppliers and between others. These key areas need be prioritized in policy discussions and decisions.

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References

2013. Census Quickstats About Housing.
2015. Doing Business. World Bank Group. Available: ⟨www.doingbusiness.org⟩.
2015. Energy Statistics [Energy Statistics, MBIE]. Available: ⟨http://www.mbie.govt.nz/info-services/sectors-industries/energy/energy-data-modelling/statistics⟩.
2015. Evaluation of Warm Up New Zealand: Heat Smart. Healthy Housing New Zealand.
2015. Levy Rates. Electricity Authority, New Zealand.
2015. New Zealand Economic Overview. Immigration New Zealand.
2015. Renting Households: National Trend. Statistics New Zealand.
2016. Clean Energy Research Programmes in Iceland. Available: ⟨www.nordicenergy.org/indicators/country/iceland⟩.
2016. Energy Strategy and Policy. Available: ⟨www.eeca.govt.nz⟩.
2016. IEA Policies and Measures Database – Iceland.
2017. EECA Business Programmes, New Zealand. Available: ⟨https://www.eecabusiness.govt.nz/sectors/commercial-and-services/⟩.
ABB, 2012. Norway Energy Efficiency Report.
Bart van Campen, R. Kirkpatrick, Panzar J., 2007. New Zealand Energy Strategy

Discussion Paper.
Barton, B., et al., 2013. Energy Cultures: Implications for Policymakers.
Barton, B., 2012. Energy Efficiency and Rental Accommodation: Dealing with Split Incentives.
Berry, S., Marker, T., Chevalier, T., 2008. Modelling the relationship between energy efficiency attributes and house price: the case of detached houses sold in the Australian capital territory in 2005 and 2006. In: World Sustainable Building Conference. Melbourne, pp. 21–25.
Boshier, J.F., 1988. Managing New Zealand's Uncertain Energy Future.
Building Research Association of New Zealand (BRANZ), 2003. Energy Use in New Zealand Households.
Byrd, H., et al., 2013. Measuring the solar potential of a city and its implications for energy policy. Energy Policy 61, 944–952.
Cabinet Policy Committee, Office of the Minister for the Environment, 2007. Government leadership in energy efficiency and climate change through the government programme.Ministry for the Environment.
Carey, B., et al., 2015. 2015 New Zealand country update. In: Proceeding, World Geothermal Congress.
Cheng, Y., Cheng, K., 2006. General study for using LED to replace traditional lighting devices. In: Power Electronics Systems and Applications, 2006. ICPESA'06. Proceedings of the 2nd International Conference On, pp. 173–177.
Davis, D., 2012. Lighting: Out with the old, in with the LED.
Dixon, R.K., et al., 2010. US energy conservation and efficiency policies: challenges and opportunities. Energy Policy 38, 6398–6408.
Energy Charter, 2005. Iceland: Regular review of energy efficiency policies.
Enova, S.F., 2014. Enova SF Annual Report 2014.
Espensen, A., et al., 2014. Nordic Tax Report – 2013.
Eusterfeldhaus, M., Barton, B., 2011. Energy efficiency: a comparative analysis of the new Zealand legal framework. J. Energy Nat. Resour. Law 29, 431.
Greenpeace Aotearoa/New Zealand, 2007. New Zealand energy revolution.
Grimes, A., et al., 2011. Warming Up New Zealand: Impacts of the New Zealand Insulation Fund on Metered Household Energy Use.
International Energy Agency (IEA), 2011. 25 Energy efficiency policy recommendations, 2011 update. Paris, France.
International Energy Agency (IEA), 2010. Energy efficiency governance: handbook, second edition. Paris, France.
International Energy Agency (IEA), 2010. Energy policies of IEA countries – New Zealand Review.
International Energy Agency (IEA), 2011. Energy policies of IEA countries: Norway, 2011 review.
International Energy Agency (IEA), 2017. IEA Statistics [IEA Statistics]. Available: ⟨http://www.iea.org/statistics/statisticssearch/⟩.
International Monetary Fund, 2011. Iceland: Advancing Tax Reform and the Taxation of Natural Resources (Tech. Rep. 11/38).
Jaffe, A.B., Stavins, R.N., 1994. The energy-efficiency gap what does it mean? Energy Policy 22, 804–810.
Kallakuri, C., Kelly, M., Vaidyanathan, S., 2016. The 2016 International Energy Efficiency Scorecard (Tech. Rep. E160). American Council for an Energy-Efficient Economy, Washington, DC.
Kelly, G., 2012. Sustainability at home: policy measures for energy-efficient appliances. Renew. Sustain. Energy Rev. 16, 6851–6860.
Keong, C.Y., 2005. Energy demand, economic growth, and energy efficiency—the Bakun dam-induced sustainable energy policy revisited. Energy Policy 33, 679–689.
Levine, M., Ürge-Vorsatz, D., Blok, K., Geng, L., Harvey, D., Lang, S., Levermore, G., Mongameli Mehlwana, A., Mirasgedis, S., Novikova, A., Rilling, J., Yoshino, H., 2007. Residential and commercial buildings. In: Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.
Maidment, C.D., et al., 2014. The impact of household energy efficiency measures on health: a meta-analysis. Energy Policy 65, 583–593.
Massey University, 2004. Energy use in the New Zealand agricultural industry-with emphasis on the dairy sector,.
Ministry of Business, Innovation & Employment, 2015. Energy in New Zealand, 2014 Calendar Year Edition. Wellington, New Zealand.
Ministry of Business, Innovation & Employment, 2016. Energy in New Zealand, 2015 Calendar Year Edition. Wellington, New Zealand. ⟨www.mbie.govt.nz/info-services/sectors-industries/energy/energy-data-modelling/publications⟩.
Ministry of Economic Development, 2009. New Zealand Energy Indicators.
Ministry of Economic Development, 2011. New Zealand Energy Strategy 2011–2021. Wellington, New Zealand.
Ministry of Economic Development, 2007. New Zealand Energy Strategy to 2050.
Nair, N.C., Zhang, L., 2009. SmartGrid: future networks for New Zealand power systems incorporating distributed generation. Energy Policy 37, 3418–3427.
National Energy Authority Iceland, 2006. Energy in Iceland.
New Zealand Business Council for Sustainable Development (NZBCSD), 2011. A Sustainable Energy Future for New Zealand by 2050: A Business View.
OECD, 2008, Eco-innovation policies in New Zealand. Environment Directorate, OECD.
Omer, A.M., 2009. Energy use and environmental impacts: a general review. J. Renew. Sustain. Energy 1, 053101.
Peng, L., et al., 2015. Analysis of energy efficiency and carbon dioxide reduction in the Chinese pulp and paper industry. Energy Policy 80, 65–75.
Power Zulauf M., A., 2011. Cutting carbon costs: Learning from Germany's energy saving program.
Quirk, I., 2009. Life-cycle Assessment and Policy Implications of Energy Efficient Lighting Technologies. University of California.
Qureshi, W.A., Nair, N.C., Farid, M.M., 2011. Impact of energy storage in buildings on electricity demand side management. Energy Convers. Manag. 52, 2110–2120.
Raza, S.A., Shahbaz, M., Nguyen, D.K., 2015. Energy conservation policies, growth and trade performance: evidence of feedback hypothesis in Pakistan. Energy Policy 80, 1–10.
Rosenberg, S.A., Winkler, H., 2011. Policy review and analysis: energy efficiency strategy for the Republic of South Africa. J. Energy South. Afr. 22, 67–79.
Tanaka, K., 2008. Assessment of energy efficiency performance measures in industry and their application for Policy. Energy Policy 36, 2887–2902.
Taylor Baines and Associates (TB&A), 2006. The impact on housing energy efficiency of market prices, incentives and regulatory requirements.
The Treasury, 2008. Briefing to the incoming Minister of finance – medium term economic challenges.
Uitdenbogerd, D., et al., 2007. Energy-related intervention success factors: a literature review.
Van den Bergh, Jeroen C.J.M., 2011. Energy conservation more effective with rebound policy. Environ. Resour. Econ. 48, 43–58.
Van den Dungen, Sanne, 2011. Minimum energy performance standards – how does New Zealand compare with other countries?.
Verma, P., Patel, N., Nair, N.C., 2016. CFL to LED transition: an analysis from harmonics perspective. In: Proceedings of the IEEE International Conference on Power SystemTechnology (POWERCON). Australia.
Verma, P., Patel, N., Nair. N.C., 2016. Power quality impacts during CFL to LED transition. In: Proceedings of the Australasian Universities Power Engineering Conference (AUPEC).
Wells, C., 2001. Total Energy Indicators of Agricultural Sustainability: Dairy Farming Case Study.
Zhou, N., Levine, M.D., Price, L., 2010. Overview of current energy-efficiency policies in China. Energy Policy 38, 6439–6452.